Closure Phase Interferometry: Lambda Andromedae

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March 19th 2009

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Thesis Project

- Interferometric modelling of active giants
- Study stellar spot characteristics
- Compare results to measure of B field
- Began with pilot study of Lam And

Committee and Collaborators

Advisor

Dr. Russel White

Committee

Dr. William Bagnuolo

Dr. Douglas Gies

Dr. Hal McAlister

Collaborators

Dr. Frank Fekel (TSU)

Dr. Greg Henry (TSU)

Dr. John Monnier (UM)

Dr. Ettore Pedretti (St. And)

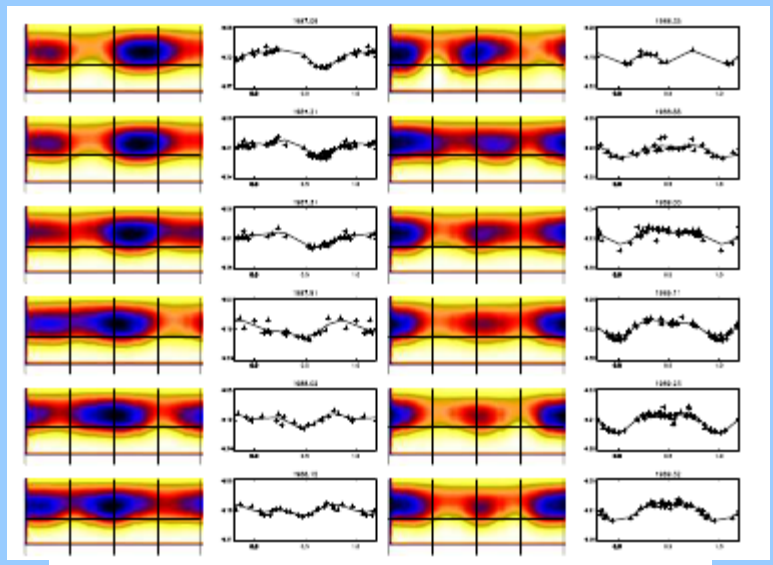
Dr. Gail Schaefer (GSU)

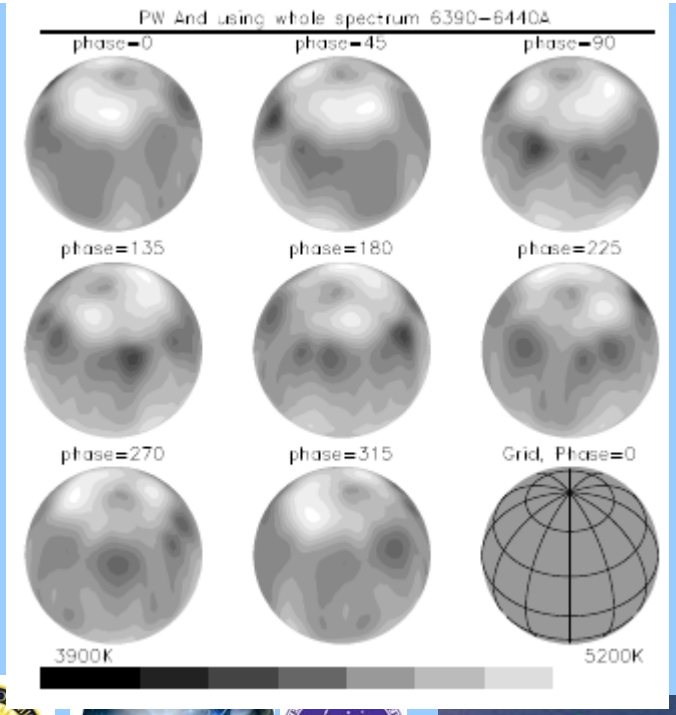
Special Thanks

Ming, Chris, PJ, CHARA team

Motivations

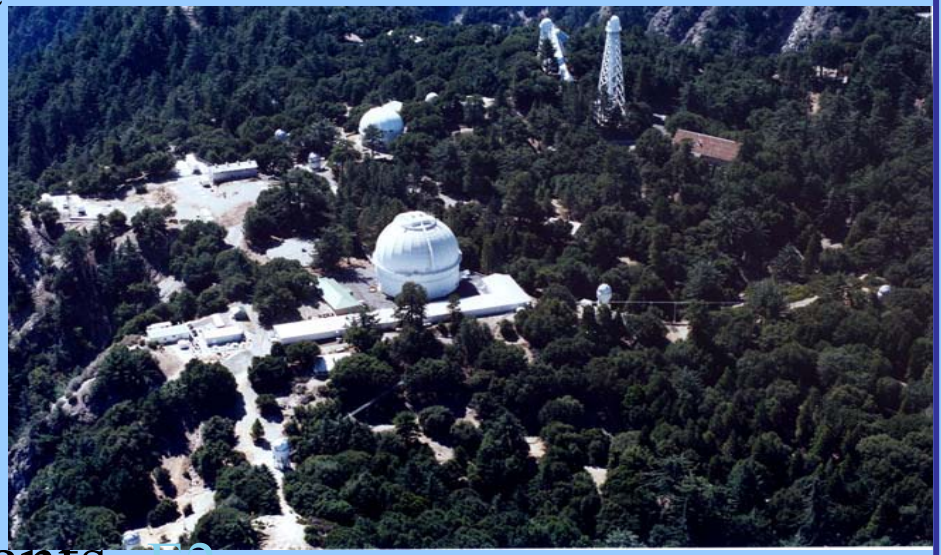
- Better understanding of spot characteristics
  - Tracer of B fields
  - Stellar rotation
- Current spot "imaging" methods problematic
  - Too little information (light curve inversion)
  - High dependance on a priori information (doppler tomography)





Target List

- Instrumentation criteria
  - Dec > 5°
  - H mag < 4th
  - Θ = 1 – 4 mas
- Target criterion
  - Single [truly or SB1] giants
  - Δ V mag > 0.1
- Initially RS CVns



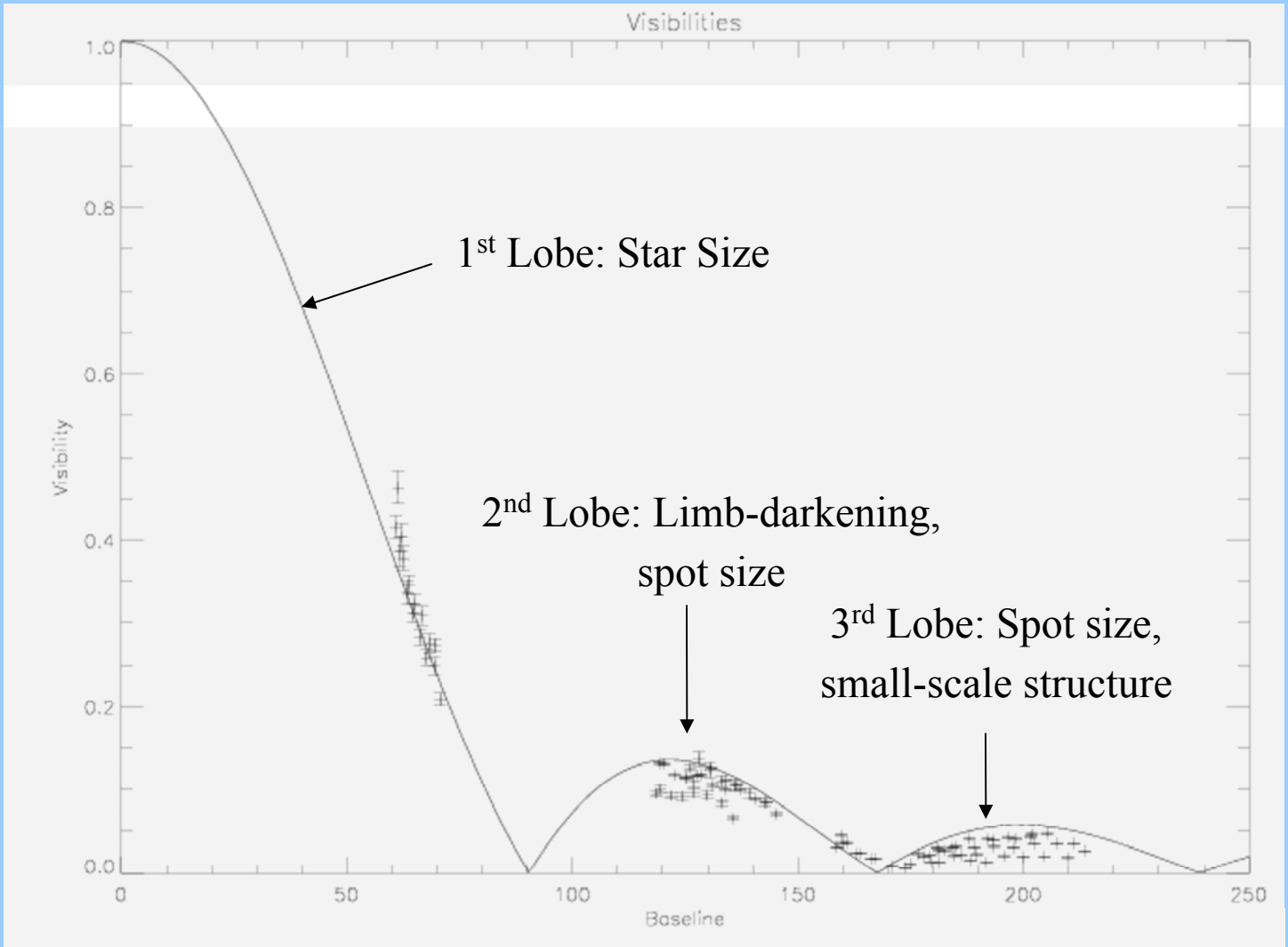
Auxillery Observations

- Hard Labor Creek Observatory (GSU) or Fairborn Observatory (TSU)
- Simultaneous or comtemporaneous
- Photometry UBV(RI)$_c$
  - Check to expected flux loss
  - Measure of effective temperature
- Spectroscopy R~30,000
  - Measure of eff. temp., log g, Hα line strength
  - Could be used to create Doppler map
  - Could be used to measure B field – Zeeman splitting

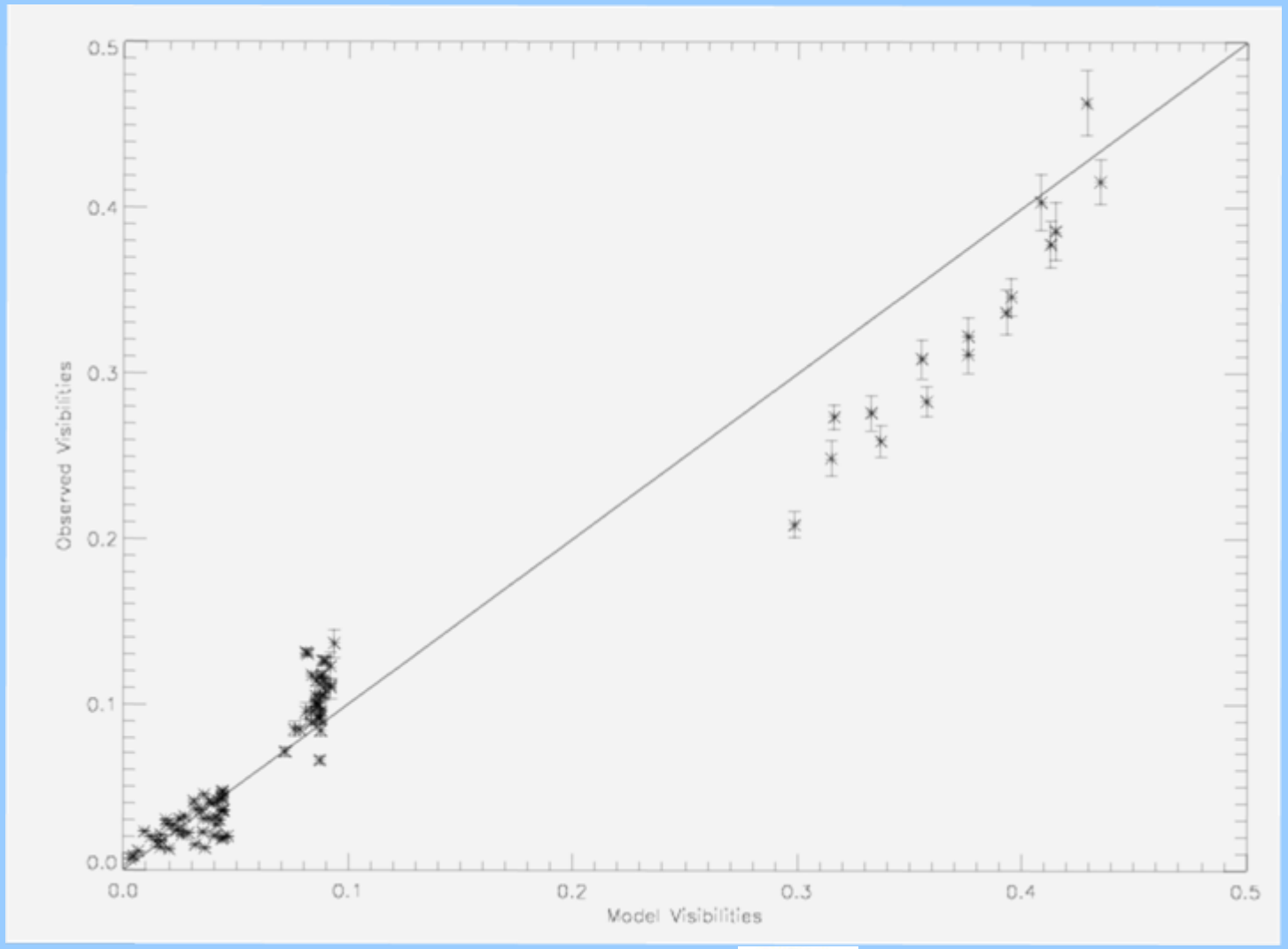
Pilot Study: Lam And

- CHARA/MIRC beam combiner
  - Prefer phase information over spot contrast
- First epoch
  - November 17, 2007
- Second epoch
  - August 18th – 21st, 2008
- Third epoch
  - September 20th, 2008

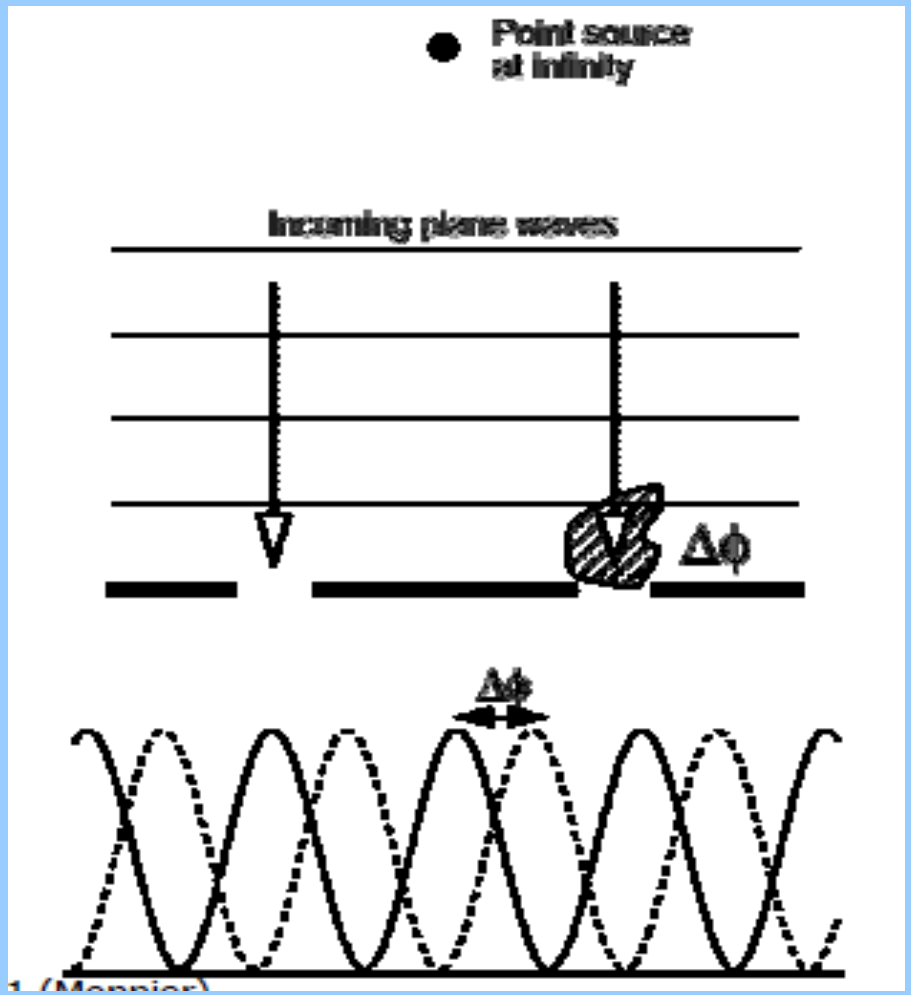
Visibility Curve



Visibility Comparison



Phase Information



Closure Phase

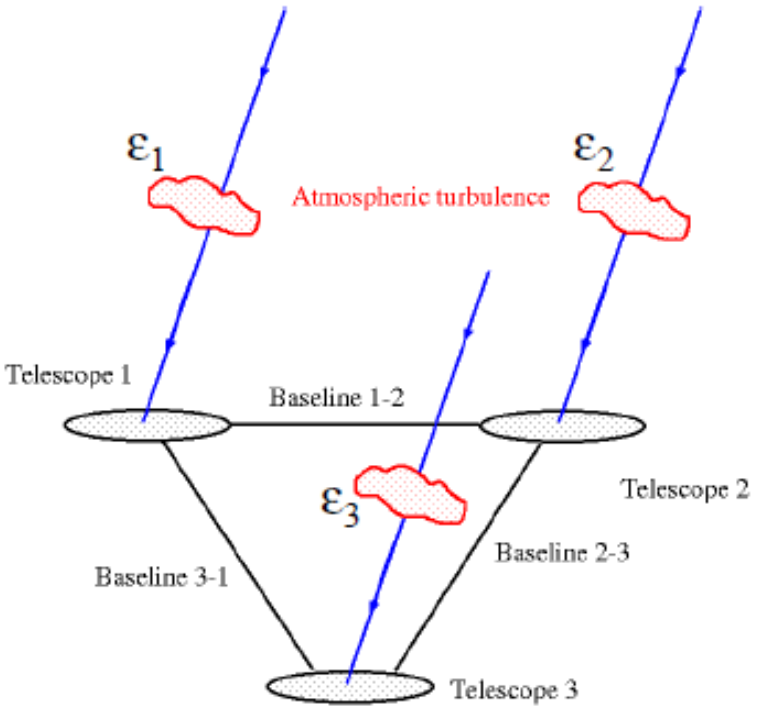
Measured Source "Antenna"

$$\Phi_{12} = \phi_{12} + \varepsilon_1 - \varepsilon_2$$
$$\Phi_{23} = \phi_{23} + \varepsilon_2 - \varepsilon_3$$
$$\Phi_{31} = \phi_{31} + \varepsilon_3 - \varepsilon_1$$

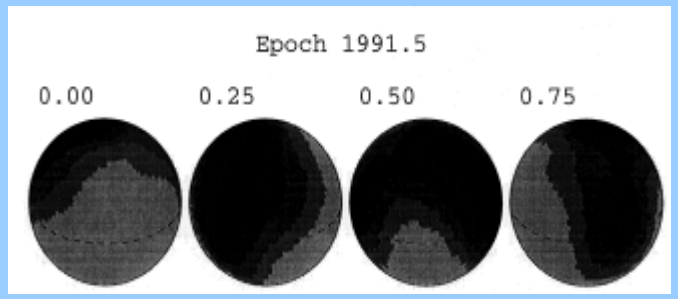
Combine $\Rightarrow$

$$\Phi_{12}+\Phi_{23}+\Phi_{31} = \phi_{12} + \phi_{23} + \phi_{31}$$

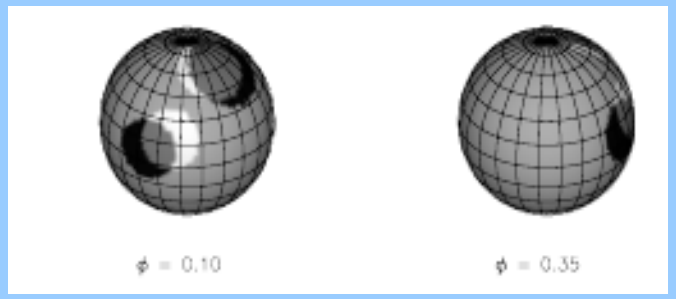
- Source terms are baseline-dependent.
- Error terms are antenna-dependent.



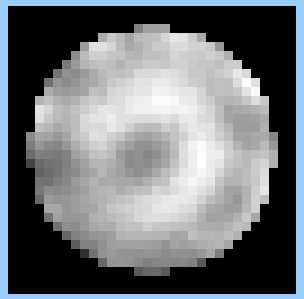
"Lambdy Andy"



Donati et al (1995)



Frasca et al (2008)



Monnier (unpub.)

Π = 38.74 ± 0.68 mas

vsini = 6.5 km/s

P_{phot} = 54.33 days

P_{orb} = 20.5212 days

H mag = 1.501

Δ V mag = 0.22

SB1, white dwarf companion

G8 III

M = 0.65 M_{sun}

R = 7.5 R_{sun}

11 yr stellar activity cycle (Hall 1991)

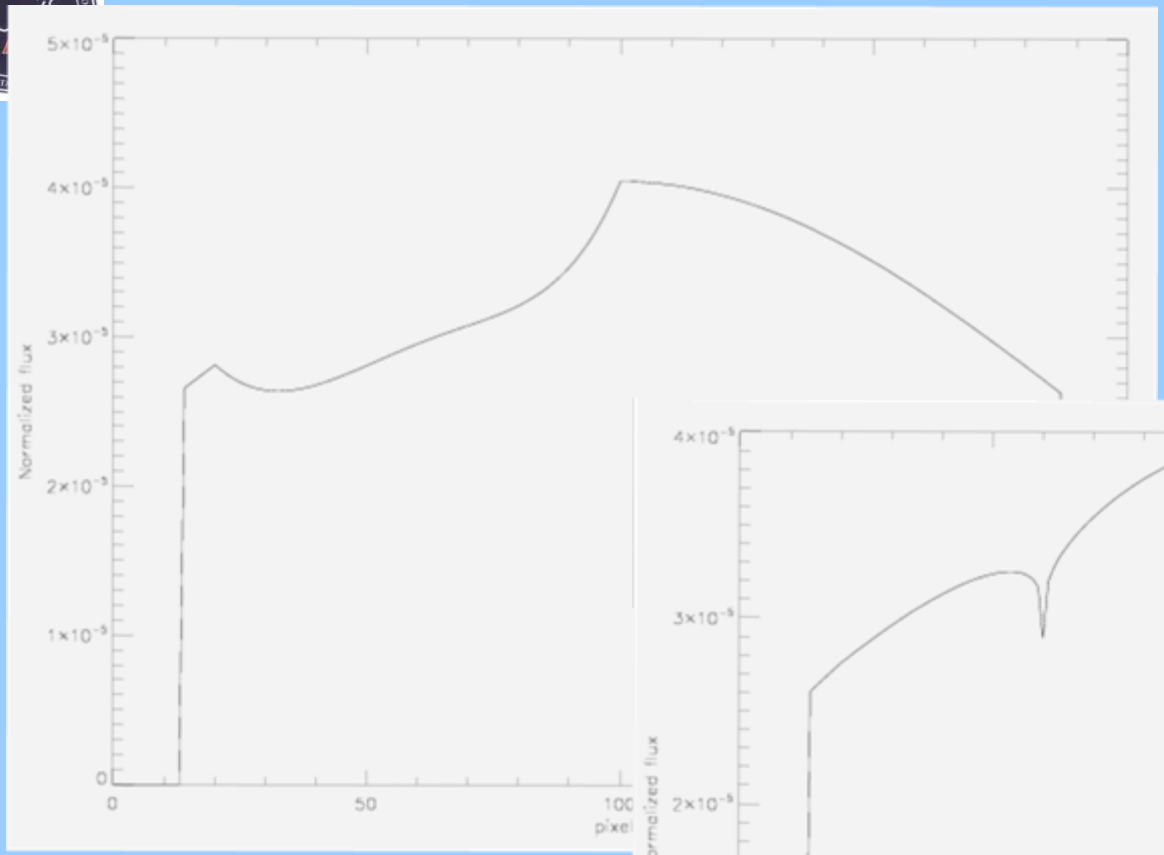
Spot Model

- 8+ parameters
  - Star size, limb-darkening coefficient, ellipticity, spot size, spot position [x,y], flux ratio, temp. profile coefficient
  - Model capable of any number of spots
- Minimization on visibility or closure phase (Filho 2008)

$$\chi^2_{V^2}(z) = \sum \frac{1}{\sigma^2_{V^2}} \left(V^2_{\text{data}} - V^2_{\text{model}}\right)^2$$

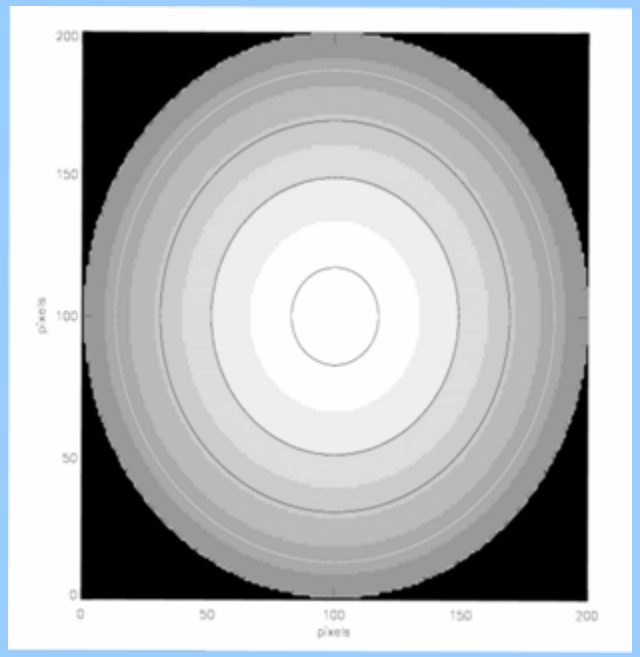
$$\chi^2_{\text{T}}(z) = \sum \frac{1}{\sigma^2_{\text{T}}} \left| e^{i\phi^{\text{data}}_{\text{T}}} - e^{i(x_1+x_2-x_3)} \right|^2$$

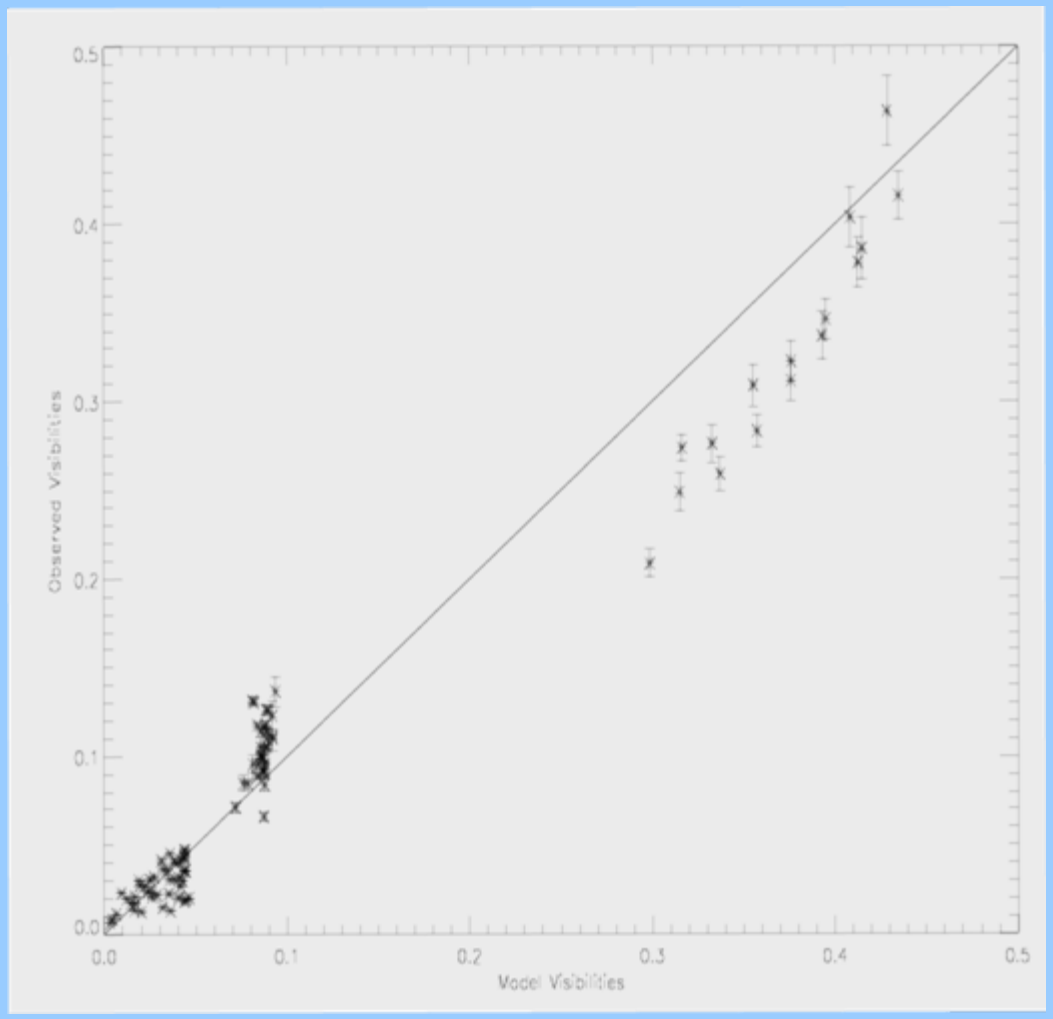
- Grey limb-darkening relation: $1-\epsilon+\epsilon\cos\Theta$


5x10⁻⁵
4x10⁻⁵
3x10⁻⁵
2x10⁻⁵
1x10⁻⁵
0
Normalized flux
0
50
100
pixel


4x10⁻⁵
3x10⁻⁵
2x10⁻⁵
1x10⁻⁵
0
Normalized flux
0
50
100
150
200
pixels

Limb-darkening Disk



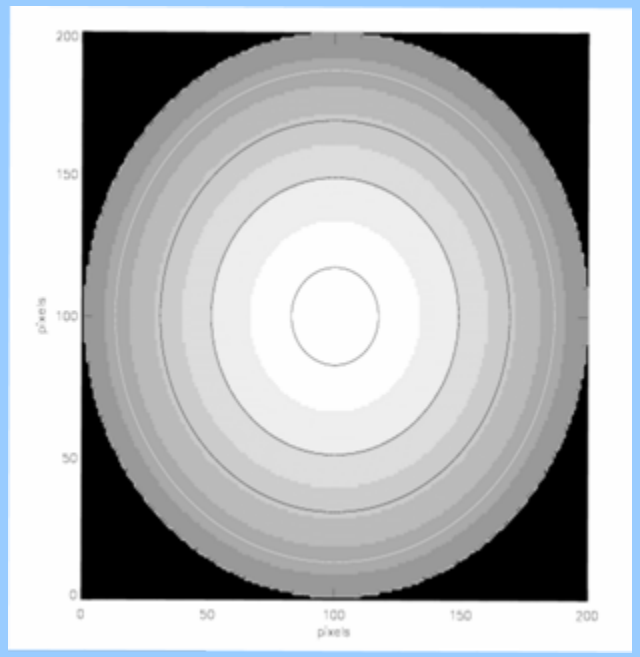


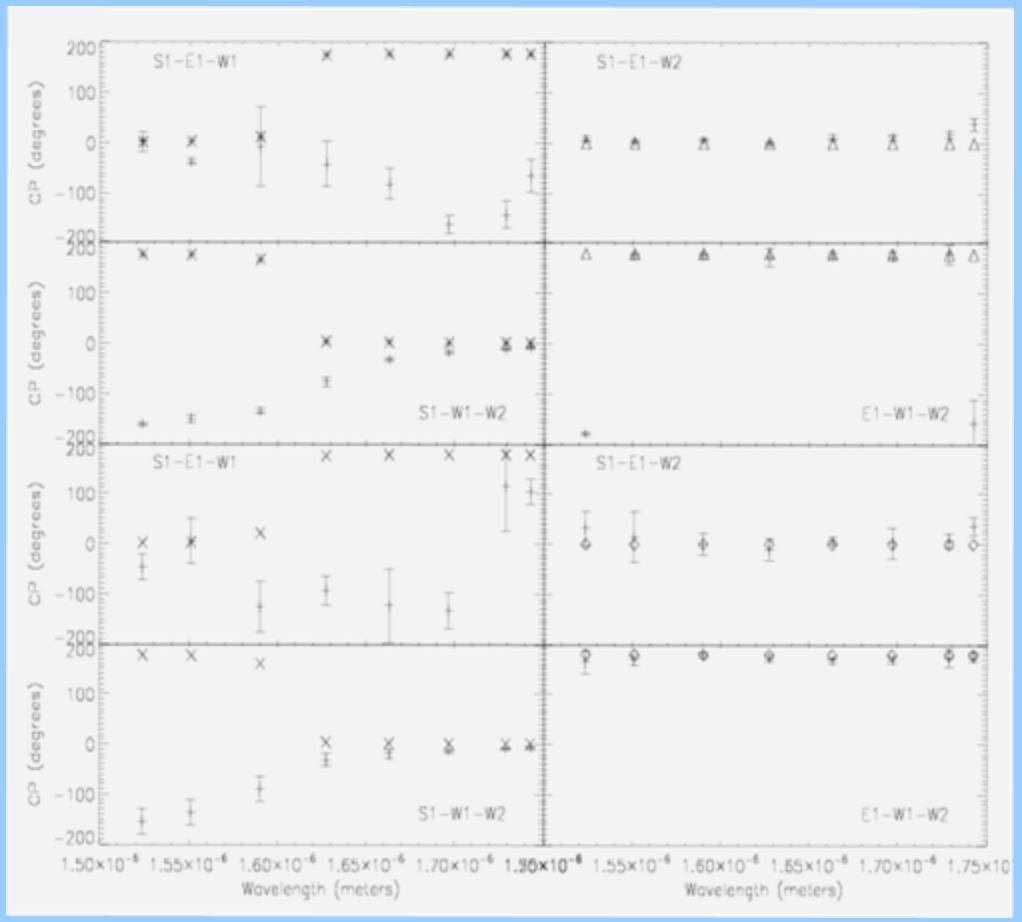
Size: 2.750 mas

Epsil: 0.462

χ^2_v: 9.818

Limb-darkening Disk





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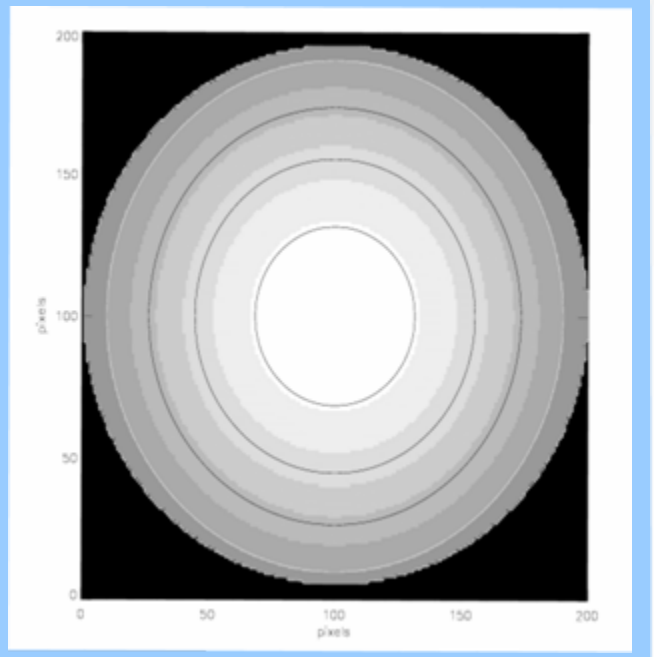
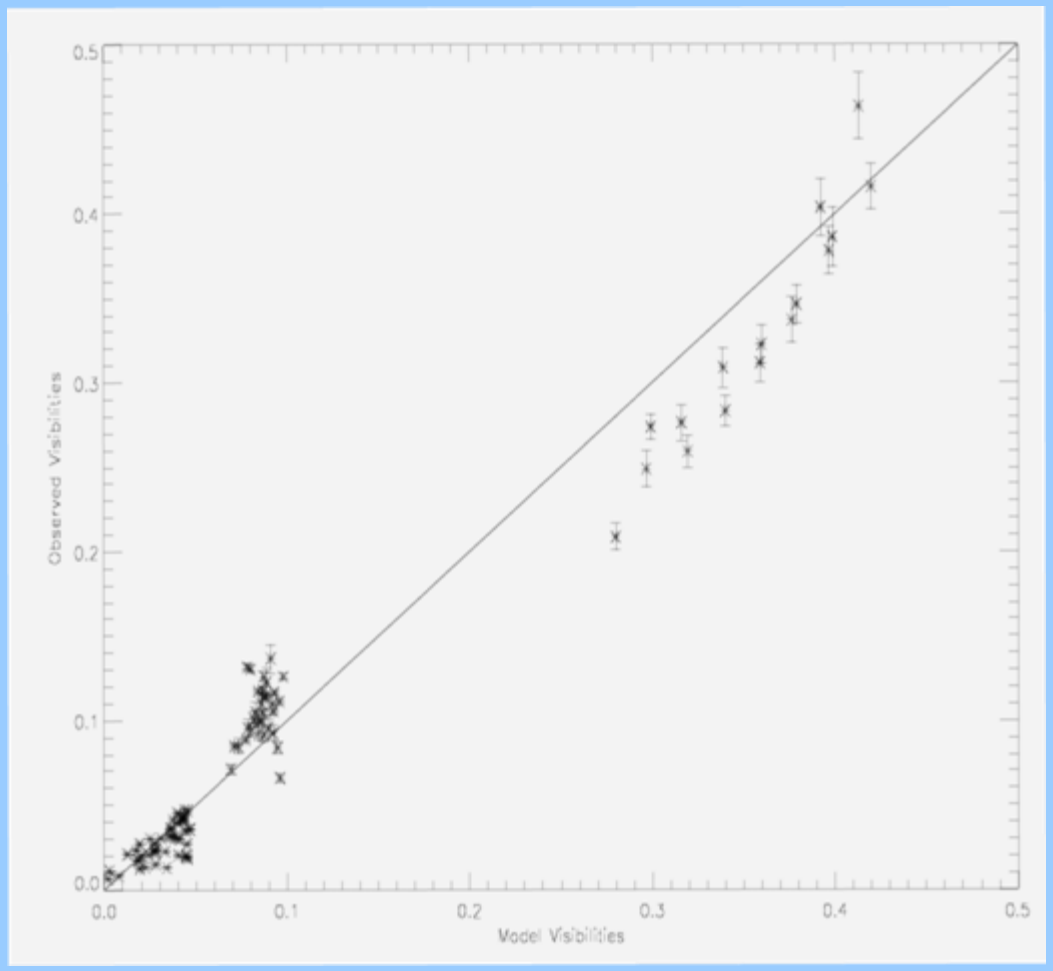
Epsil: 0.462

χ^2_v: 9.818

Elongated Limb-darkening Disk





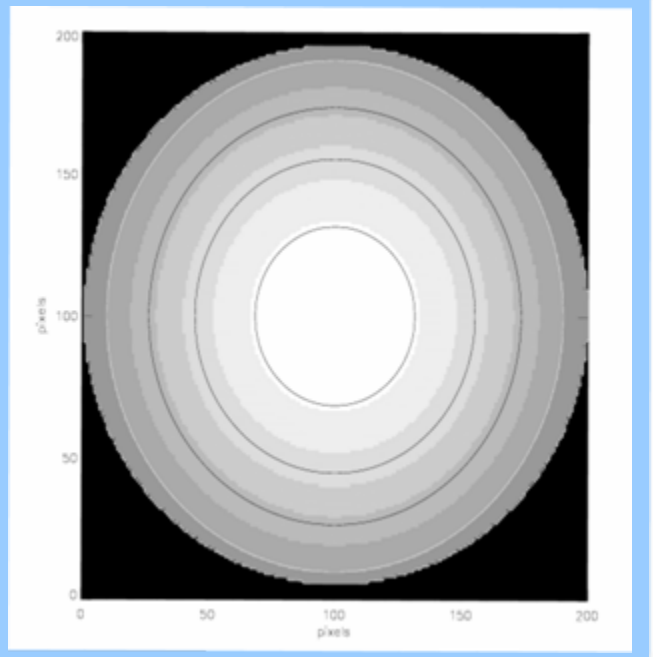
Size: 2.819 mas

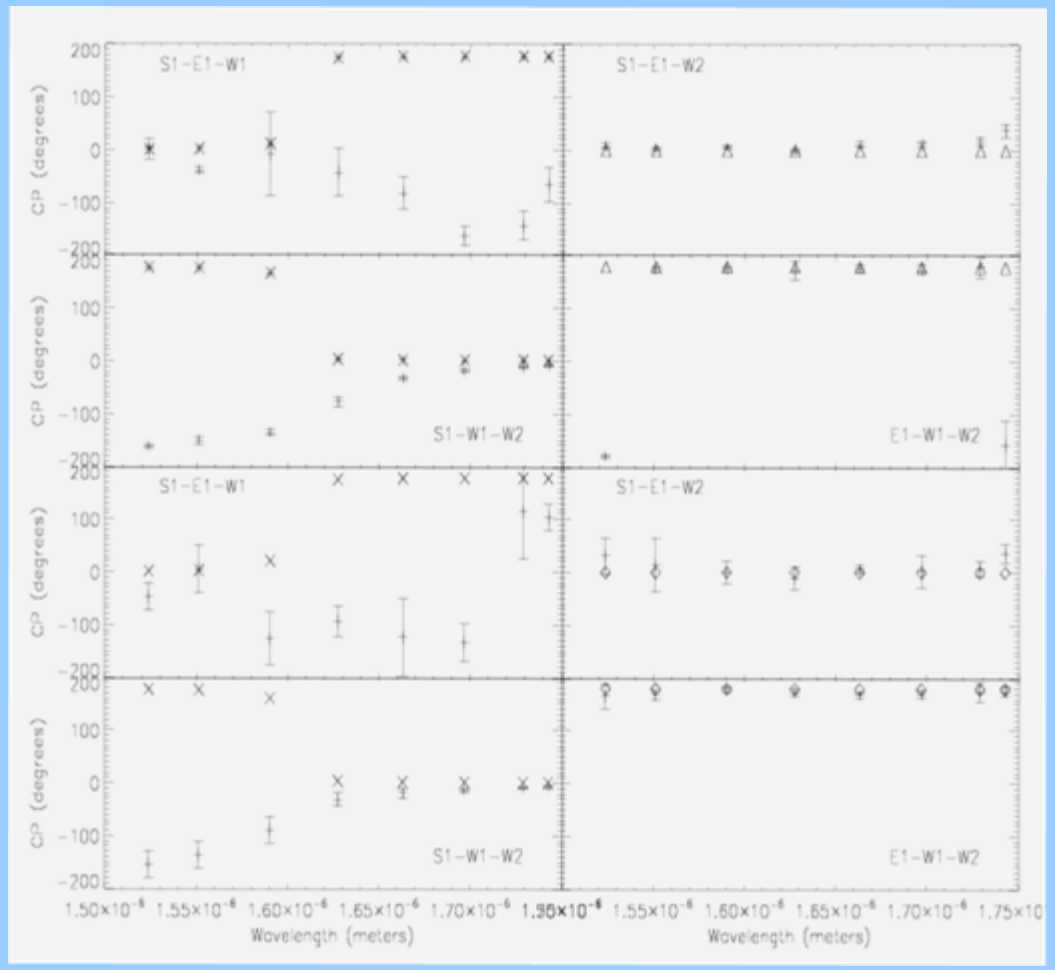
Epsil: 0.467

Ellip 0.0469

χ^2_v: 8.109

Elongated Limb-darkening Disk





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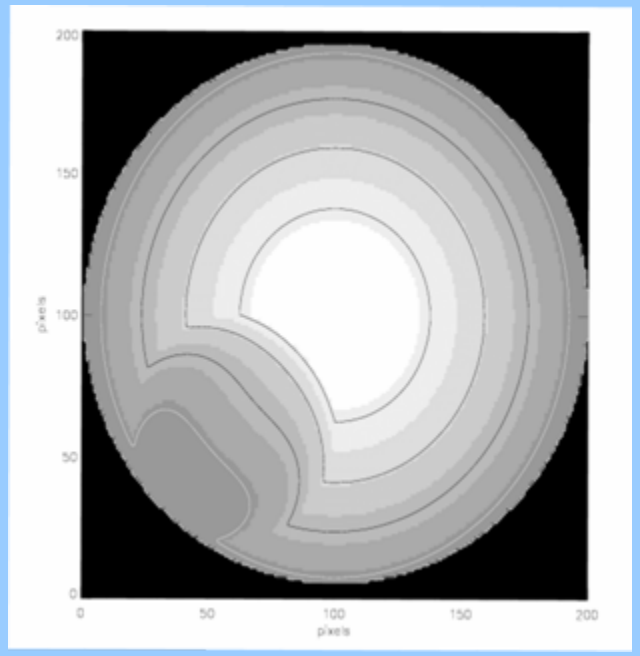
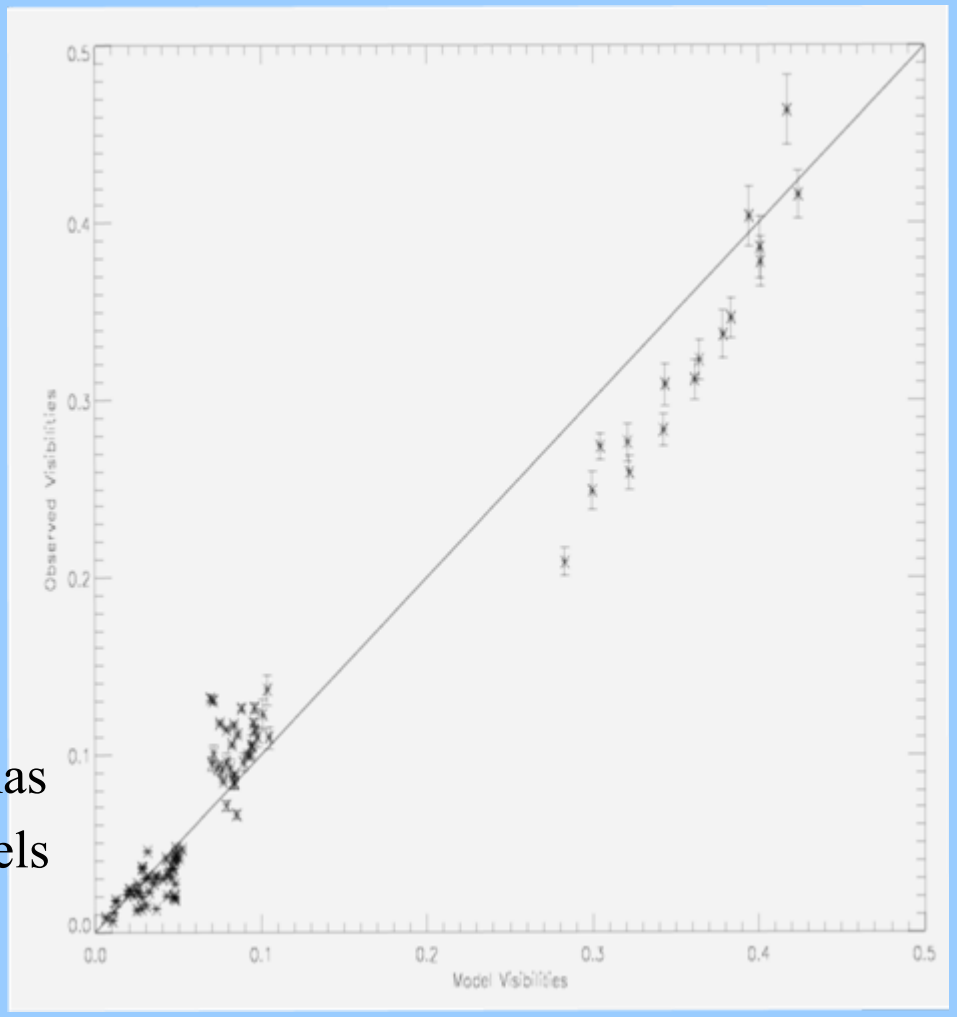
Ellip 0.0469

χ^2_v: 8.109

Elongated Limb-darkening Disk w/ Spot





Star Size: 2.819 mas

Epsil: 0.467

Ellip 0.0469

χ^2_V: 10.847

χ^2_C: 0.016

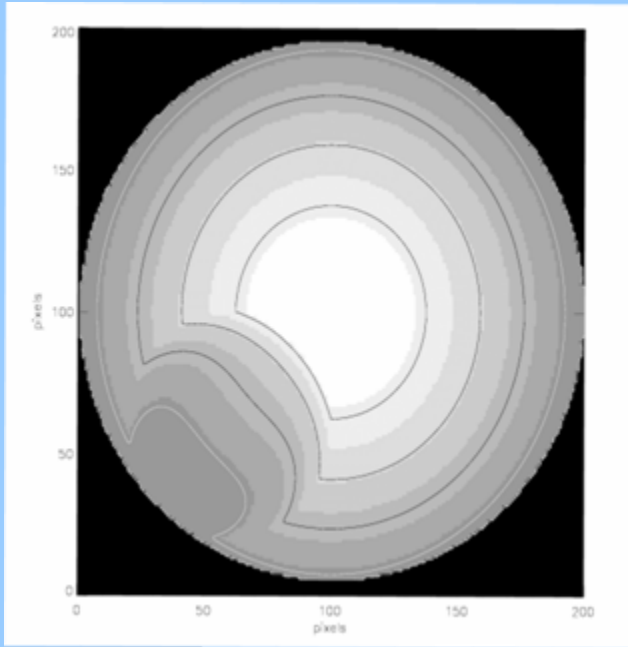
Spot Size: 1.13 mas

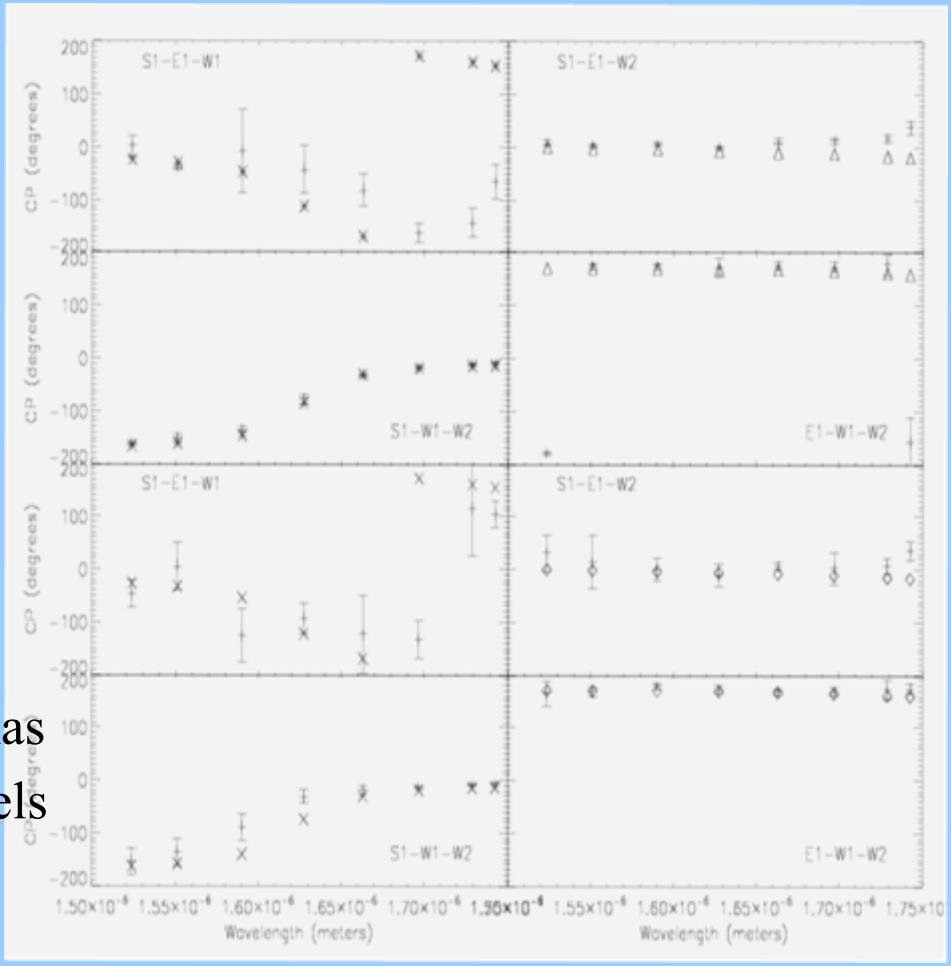
80 pixels

x: 60

y: 60

Elongated Limb-darkening Disk w/ Spot





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The News So Far...

- Closure phase show assymmetries
- Simple models insufficient
- Strong signs towards spotted surface

Future Plans

- Improved method of minization
- Addition of elongation position angle
- More complicated spot structures
- Apply to multiple epochs of data
- Magic happens → Graduate